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Report No. 8926-149

Material - Adhesives - Structural - FM 58
(Bloomingdale Rubber Co.)

Qualification Tests for Metal-to-Metal and
Honeycomb Core Panel Bonding of
Aluminum Alloys

H. H. Hunt, E. E. Bergstrom, G. L. Picotte, E. E. Keller

2 June 1959

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Contract AF33(657)-8926



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Material - Adhesives - Structural - FM 58
(Bloomington Rubber Co.)

Qualification Tests for Metal-to-Metal and
Honeycomb Core Panel Bonding of
Aluminum Alloys

Abstract:

Lap shear tensile and peel test specimens, incorporating 2024-T3 aluminum alloy sheet, and BR-223 adhesive primer and FM 58 film adhesive (both Bloomington Rubber Co. adhesives) were prepared and tested in accordance with Specification Mil-A-5090B and Convair Specification 22-01310, respectively. In addition, 1/2" thick aluminum alloy honeycomb panels consisting of 0.020" thick clad 2024-T3 aluminum alloy face plates and 5052 aluminum alloy honeycomb core and the two adhesives mentioned were prepared and tested in accordance with Convair Specification 22-00401. The curing procedure involved in specimen preparation consisted of pre-curing at 175°F for 60 minutes and bonding at 350°F for 60 minutes under a pressure of 50 psi. The tests showed the FM 58/BR-223 adhesive system in conformance with Specification Mil-A-5090B requirements for tensile shear strength at -67°F., room temperature and 180°F.; and after exposure to JP-4 fuel, Skydrol 500, 100% relative humidity and salt spray. The adhesive system also was shown in conformance with flexural and peel strength requirements for aluminum honeycomb panel construction. Some of the peel tests indicated that the adhesive system could be used successively for large metal-to-metal bonds.

Reference: Hunt, H. H., Bergstrom, E., Picotte, G. L., Keller, E. E.,
"Evaluation of the FM 58 Adhesive System," General Dynamics/
Convair Report MP 59-071, San Diego, California, 2 June 1959.
(Reference attached).

SAN DIEGO

STRUCTURES & MATERIALS LABORATORIES

REPORT MP 59-071

DATE 2 June 1959

MODEL 30

TITLE

REPORT NO. MP 59-071

EVALUATION OF THE FM-58 ADHESIVE SYSTEM

MODEL: 30

CONTRACT NUMBER: CPO 58-51A & 58-51B

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H. Hunt/B. Bergstrom

G. Piotto

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E. E. Keller
E. E. Keller

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APPROVED BY E. F. Strong
E. F. Strong, Chief
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NO. OF PAGES 15

NO. OF DIAGRAMS 9

NO. OF PA
NO. OF DI
W. M. Sutherland
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REVISIONS

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ANALYSIS
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SAN DIEGO

PAGE 1
REPORT NO. MP 59-071
MODEL 30
DATE 2 June 1959

INTRODUCTION:

The development of the FM-58 adhesive system was initiated by the Bloomingdale Rubber Company of Aberdeen, Maryland, at the request of Convair, San Diego, Engineering Department.

OBJECT:

1. To determine if the FM-58/BR-223 adhesive system meets the qualification test requirements of MIL-A-5090B and Convair Specifications 22-00401 and 22-01310.

CONCLUSIONS:

1. The FM-58/BR-223 adhesive system meets the requirements of MIL-A-5090B for tensile shear strength at -67°F, room temperature, 180°F; and after exposure to JP-4 fuel, Skydrol 500, 100% relative humidity and salt spray.

The material meets the flexural and drum peel strength requirements for core to skin production bonding of Convair Specification 22-00401.

The metal-to-metal peel test specimens made by bonding 16" x 16" skins do not meet the requirements of Convair Specification 22-01310 for T-peel strength at room temperature. Results do indicate that FM-58 may be used successfully for large area metal-to-metal bonds.

ANALYSIS

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PAGE 2
REPORT NO. MP 59-071
MODEL 30
DATE 2 June 1959

TEST SPECIMENS:**Tensile Shear Specimens:**

The 4" x 9" lap joint specimens were prepared in sufficient quantities from .064" 2024-T3 clad aluminum alloy conforming geometrically to Figure 2 in MIL-A-5090B. All edges of the panels to be within the completed bonded lap-joints were milled true and smooth before the panels were cleaned and bonded.

Peel Specimens:

Specimens .020" x 1" x 10" were obtained by subsequent shearing of two .020" x 16" x 16" 2024-T3 clad aluminum alloy (Specification QQ-A-362) bonded sheets. Specimens were of the size shown in Figure 3 of 22-01310 and conformed to the applicable requirements of 22-01308, paragraph 4.4.2.1.1. and 4.4.2.2.1. Care was taken to avoid crushing, scratching, denting and delamination of the test specimens.

Honeycomb Specimens:

Two sandwich panels 16" x 16" were fabricated using .020" thick 2024-T3 clad aluminum alloy skins and 0.500 inch thick 5052 honeycomb core in accordance with Specification MIL-C-7438B, Type 1B. Five 3" x 16" specimens with the core ribbon parallel to the 16 inch dimension were cut from each panel.

Adhesive Tape & Primer:

The adhesive tape (FM-58) and primer (BR-223) used in making the tests outlined in this report were procured from the Bloomingdale Rubber Company Laboratories. FM-58 was furnished in a roll 48 inches wide by 36 yards long with each .015 mil layer separated by a non-blocking film backing. Film weight was 0.086 lbs/sq.ft. BR-223 primer was supplied in one pint containers designated as Batch No. C-33-2 manufactured 12/18/58.

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SAN DIEGO**PAGE** 3**REPORT NO.** MP 59-071**MODEL** 30**DATE** 2 June 1959**TEST PROCEDURE:****Processing - Preparation for Bonding****Surface Preparation - Metal**

1. Hand wipe with methyl ethyl ketone and clean cheesecloth.
2. Sodium dichromate - sulfuric acid etch 10 - 13 minutes at 150°F ± 10°F in a solution comprised of:

Sodium Dichromate	4 parts by weight
Sulfuric Acid	10 parts by weight
Water	30 parts by weight
3. Tap water rinse.
4. Distilled water rinse.
5. Oven dry 20 minutes at 150°F in an air circulating oven, after checking for a water break free surface.
6. Cool to room temperature.

Surface Priming:

1. Shake BR-223, thinned to 10% solids with methyl isobutyl ketone, in a paint shaker for 15 minutes.
2. Spray prime on faying surfaces, using BR-223, to a dried film thickness of .0005" to .001".
3. Air dry prime for 30 minutes at room temperature followed by 60 minutes at 175°F in an air circulating oven.
4. Cool to room temperature.

Cleaning of Core:

Core was cleaned by spraying liberally from both sides with uncontaminated aliphatic naphtha conforming to Federal Specification TT-N-95a. Care was taken not to allow core to stand in the liquid during this operation.

Bonding Procedure - Metal-To-Metal:

1. FM-58 film was interposed between the primed faying surfaces and the specimens were assembled for bonding and curing in a 3 platen electrically heated hydraulic K-M press Model No. 2309 for 60 minutes at 350°F and 50 PSI. Silicone rubber strips were placed above the bond area prior to placing the assembly in the press to insure pressure equalization during the cure.

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PAGE 4
REPORT NO. MP 59-071
MODEL 30
DATE 2 June 1959

TEST PROCEDURE: (Cont'd)**Bonding Procedure - Sandwich Assemblies:**

1. The FM-58 film was interposed between the primed faying metal skins and honeycomb core in such a manner that the scrim cloth side of the film was adjacent to the cleaned, but unprimed aluminum core.
2. The assembly was placed in a Black Brother's press, Model No. D-1006 with 18" x 18" electrically heated platens using the bonding cycle specified for metal-to-metal curing. The release of pressure following bonding was accomplished when the temperature was reduced to 150°F.

TESTING:**Tensile Shear Testing:**

Specimens were tested in accordance with paragraph 4.3.2.1 of Military Specification MIL-A-5090B at the following temperatures:

- (a) Low temperature ($-67^{\circ} \pm 2^{\circ}\text{F}$): Specimens were maintained at this temperature by using a mixture of dry ice and isopropyl alcohol.
- (b) Standard (room) temperature ($75^{\circ} \pm 5^{\circ}\text{F}$).
- (c) Elevated temperature ($180^{\circ} \pm 2^{\circ}\text{F}$): Specimens were maintained at this temperature by using a bath of electrically heated Dow Corning 710 fluid controlled by a Leeds and Northrup Company Speedomax - type G recorder - controller.

Peel Testing:

Specimens were tested for peel strength in the adhesive laboratories drum-type peel tester using the procedure listed in Convair Report 8-01310. Low temperature ($-67^{\circ} \pm 2^{\circ}\text{F}$) was obtained by using a mixture of dry ice and isopropyl alcohol.

Flexural Honeycomb Testing:

Specimens were loaded and tested at room temperature as shown in Specification O-05033, Figure 1. A skin compression stress of 50,000 psi and a core shear stress of 211 psi and an "A" distance of 4.75 inches was used. Testing was accomplished by means of a Cal-tester Model #TH-5. Rate of loading was 200 pounds per minute.

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PAGE 5
REPORT NO. MP 59-071
MODEL 30
DATE 2 June 1959

TESTING: (Cont'd)

Peel Honeycomb Tests:

Peel tests were conducted in accordance with Specification 22-01310 on the failed flexural specimens at room temperature, using a climbing drum peel tester at a rate of 4 to 12 inches per minute.

Low temperature ($-65^{\circ} \pm 2^{\circ}\text{F}$) peel testing was accomplished by using dry ice and a Missimer Cold Box Model FML4-85x1000 regulated by a Model 402 Missimer Controller. Specimens were not flexurally tested prior to low temperature peeling.

RESULTS:

The results of testing and calculations are given in the following tables. It is possible to refer to Table I for a simultaneous verification of the results of all the tests performed.

NOTE: The test data from which this report was prepared are recorded in Materials and Processes Test Laboratories Data Book No. 3005.

ACCESS NO.

Title: MATERIAL - ADHESIVES - STRUCTURAL - FM 58 (BLOOMINGDALE RUBBER CO.).
QUALIFICATION TESTS FOR METAL-TO-METAL AND HONEYCOMB CORE BONDING
OF ALUMINUM ALLOYS.

Authors: Hunt, H. H., Bergstrom, E. E., Picotte, G. L., Keller, E. E.

Report No.: 8926-149

Date: 2 June 1959

Contract: Model 30, Commercial

Contractor: General Dynamics/Convair

ABSTRACT: Lap shear tensile and peel test specimens, incorporating 2024-T3 aluminum alloy sheet, and BR-223 adhesive primer and FM 58 film adhesive (both Bloomingdale Rubber Co. adhesives) were prepared and tested in accordance with Specification Mil-A-5090B and Convair Specification 22-01310, respectively. In addition, 1/2" thick aluminum alloy honeycomb panels consisting of 0.020" thick clad 2024-T3 aluminum alloy face plates and 5052 aluminum alloy honeycomb core and the two adhesives mentioned were prepared and tested in accordance with Convair Specification 22-00401. The curing procedure involved in specimen preparation consisted of pre-curing at 175°F for 60 minutes and bonding at 350°F for 60 minutes under a pressure of 50 psi. The tests showed the FM 58/BR-223 adhesive system in conformance with Specification Mil-A-5090B requirements for tensile shear strength at -67°F., room temperature and 180°F.; and after exposure to JP-4 fuel, Skydrol 500, 100% relative humidity and salt spray. The adhesive system also was shown in conformance with flexural and peel strength requirements

(Continued)

ACCESS NO.

Title: MATERIAL - ADHESIVES - STRUCTURAL - FM 58 (BLOOMINGDALE RUBBER CO.).
QUALIFICATION TESTS FOR METAL-TO-METAL AND HONEYCOMB CORE BONDING
OF ALUMINUM ALLOYS.....Continued

for aluminum honeycomb panel construction. Some of the peel tests indicated that the adhesive system could be used successively for large metal-to-metal bonds.

15 pages, 13 tables, 9 references.

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PAGE 6
REPORT NO. MP 59-071
MODEL 30
DATE 2 June 1959

REFERENCES

1. "Technical Data FM-58 Structural Adhesive," Bloomingdale Rubber Company, October 1, 1958.
2. "Adhesive; Airframe Structural, Metal to Metal", Military, MIL-A-5090B, July 1, 1954.
3. "Adhesive Bonded Metal; Process and Inspection Requirements", Military, MIL-A-9067A, Jan. 10, 1955.
4. "Core Material; Aluminum Honeycomb", Military, MIL-C-7438B, December 21, 1953.
5. "Adhesive; Metallic Structural, Sandwich Construction", Military, MIL-A-25463, January 14, 1958.
6. "Specification for Sandwich Construction", Convair 0-05033F, October 31, 1950.
7. "Bonded Aluminum Alloy Aircraft Parts; Adhesive Process and Inspection Requirements", 22-01308G, February 6, 1958.
8. "Peel Test Procedure for Adhesive Quality", Convair, 22-01310 C, March 27, 1958.
9. "Aluminum Honeycomb Sandwich Panels and Components Processing Of", Convair, 22-00401B, February 5, 1958.

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PAGE 7
REPORT NO. MP 59-071
MODEL 30
DATE 2 June 1959

TABLE 1

SUMMARY OF TEST RESULTS

Spec.	Test	Specification Requirement	Test Results For FM 58/BR 223
MIL-A-5090B	Standard (Room) Temp. Shear Strength	2500 PSI	3922 PSI
	-67° ± 2°F Shear Strength	2500 PSI	*2972 PSI
	+180° ± 2°F Shear Strength	1250 PSI	2739 PSI
	Shear Strength After 7 Days Immersion In JP-4 Fuel	2250 PSI	4123 PSI
	Shear Strength After 7 Days Immersion In Skydrel 500	2250 PSI	4295 PSI
	Shear Strength After 30 Days Salt Spray Exposure	2250 PSI	4088 PSI
	Shear Strength After 30 Days 100% Relative Humidity Exposure	2250 PSI	3042 PSI
Convair 22-01310	Standard (Room) Temp. Peel Strength	30 Lbs./In.Width	27 Lbs./In.Width
	-67° ± 2°F Peel Strength	None	13 Lbs./In.Width
	Standard (Room) Temp. Peel Strength After 7 Days Immersion In JP-4 Fuel	None	26 Lbs./In.Width
	Standard (Room) Temp. Peel Strength After 7 Days Immersion In Skydrel 500	None	26 Lbs./In.Width

* Metal "pull out" occurred at pin hole in the majority of the specimens tested at -67°F, thereby precluding a bond type failure.

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PAGE 8
 REPORT NO. MP 59-071
 MODEL 30
 DATE 2 June 1959

TABLE 1 (CONT'D)

Spec.	Test	Specification Requirement	Test Results For FM 58/BR 223
ALUMINUM HONEYCOMB			
Convair 22-00401	Standard (Room) Temp. Compression Stress Peel Strength	50,000 PSI 60 In.-Lbs.	55,828 PSI 112 In.-Lbs.
	-65° ± 2°F Peel Strength	45 In.-Lbs.	57 In.-Lbs.
	Standard (Room) Temp. Compression Stress Peel Strength After 7 Days Immersion In JP-4 Fuel	None None	56,201 PSI 112 In.-Lbs.
	Standard (Room) Temp. Compression Stress Peel Strength After 7 Days Immersion In Skydrol 500	None None	55,828 PSI 116 In.-Lbs.
	Standard (Room) Temp. Compression Stress Peel Strength After 30 Days 100% Relative Humidity Exposure	None None	54,147 PSI 97 In.-Lbs.

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PAGE 9
REPORT NO. MP 59-071
MODEL 30
DATE 2 June 1959

TABLE 2

STANDARD (ROOM) TEMPERATURE SHEAR STRENGTHS

Specimen No.	Shear Strength	% Failure		*C.G.L.T.
	PSI	Adhesive	Cohesive	Mils
1A	3991	60	40	7
2A	3954	60	40	7
3A	3973	70	30	8
4A	3945	70	30	7
5A	3873	60	40	7
6A	3864	70	30	7
7A	3852	80	20	8

Avg. 3922

TABLE 3

-67° ± 2°F SHEAR STRENGTHS

Specimen No.	Shear Strength	% Failure		*C.G.L.T.
	PSI	Adhesive	Cohesive	Mils
1C	3264	100	0	8
2C	3339	**		8
3C	2972	**		6
4C	2073	**		8
5C	3389	**		8
6C	2991	**		6
7C	2773	**		9

Avg. 2972

*C.G.L.T. = Cured glue line thickness.

**Note: Metal "pull out" occurred at pin hole. Bond did not rupture.

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PAGE 10
 REPORT NO. MP 59-071
 MODEL 30
 DATE 2 June 1959

TABLE 4

+180° ± 2° SHEAR STRENGTHS

Specimen No.	Shear Strength	% Failure		*C.G.L.T.
	PSI	Adhesive	Cohesive	Mils
1B	2555	100	0	8
2B	2945	100	0	8
3B	2944	100	0	6
4B	2722	100	0	8
5B	2518	100	0	8
6B	2545	100	0	6
7B	<u>2643</u>	100	0	9

Avg. 2739

TABLE 5

**STANDARD (ROOM) TEMPERATURE SHEAR STRENGTHS AFTER
 7 DAYS IMMERSION IN JP-4 FUEL**

Specimen No.	Shear Strength	% Failure		*C.G.L.T.
	PSI	Adhesive	Cohesive	Mils
1D	4027	80	20	8
2D	4411	80	20	7
3D	4102	80	20	8
4D	4182	80	20	8
5D	4000	80	20	8
6D	4018	80	20	8
7D (Control)	<u>4037</u>	50	50	9

Avg. 4123

Note: Control specimen cut from panel prior to exposure.

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PAGE 11
REPORT NO. MP 59-071
MODEL 30
DATE 2 June 1959

TABLE 6

STANDARD (ROOM) TEMPERATURE SHEAR STRENGTHS AFTER
7 DAYS IMMERSION IN SKYDROL 500

Specimen No.	Shear Strength PSI	% Failure		*C.G.L.T. Mils
		Adhesive	Cohesive	
1E	4130	80	20	8
2E	4423	80	20	7
3E	4241	80	20	8
4E	4398	50	50	7
5E	4160	20	80	11
6E	4417	80	20	5
7E (Control)	<u>3759</u>	60	40	9

Avg. 4295

TABLE 7

STANDARD (ROOM) TEMPERATURE SHEAR STRENGTHS AFTER
30 DAYS SALT SPRAY EXPOSURE

Specimen No.	Shear Strength PSI	% Failure		*C.G.L.T. Mils
		Adhesive	Cohesive	
1F	4009	50	50	6
2F	4028	50	50	5
3F	4241	50	50	5
4F	4167	50	50	5
5F	3926	50	50	5
6F	4157	50	50	7
7F (Control)	<u>4000</u>	50	50	9

Avg. 4088

Note: Control specimen cut from panel prior to exposure.

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PAGE 12

REPORT NO. MP 59-071

MODEL 30

DATE 2 June 1959

TABLE 8STANDARD (ROOM) TEMPERATURE SHEAR STRENGTHS AFTER
30 DAYS 100% RELATIVE HUMIDITY EXPOSURE

Specimen No.	Shear Strength	% Failure		*C.G.L.T.
	PSI	Adhesive	Cohesive	Mils
1G	3048	20	80	6
2G	2889	20	80	6
3G	3038	20	80	4
4G	3104	20	80	7
5G	3240	20	80	6
6G	2934	20	80	7
7G (Control)	<u>3602</u>	20	80	5

Avg. 3042

TABLE 9

STANDARD (ROOM) TEMPERATURE PEEL STRENGTHS

Specimen No.	Peel Strength	% Failure		*C.G.L.T.
	Lbs./In.Width	Adhesive	Cohesive	Mils
1A	25	10	90	12
2A	30	50	50	12
3A	35	50	50	12
4A	22	50	50	12
5A	25	10	90	12
6A	<u>24</u>	10	90	12

Avg. 27

Note: Control specimen cut from panel prior to exposure.

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PAGE 13

REPORT NO. MP 59-071

MODEL 30

DATE 2 June 1959

TABLE 10**-67° ± 2° PEEL STRENGTHS**

Specimen No.	Peel Strength Lbs./In.Width	% Failure		*C.G.L.T. Mils
		Adhesive	Cohesive	
1C	11	0	100	13
2C	13	0	100	12
3C	14	0	100	12
4C	13	0	100	12
5C	14	0	100	12
6C	13	0	100	12

Avg. 13

TABLE 11**STANDARD (ROOM) TEMPERATURE PEEL STRENGTHS AFTER
7 DAYS IMMERSION IN JP-4 FUEL**

Specimen No.	Peel Strength Lbs./In.Width	% Failure		*C.G.L.T. Mils
		Adhesive	Cohesive	
1D	28	0	100	12
2D	28	0	100	13
3D	26	10	90	12
4D	22	10	90	13
5D	26	0	100	13
6D	28	10	90	12

Avg. 26

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SAN DIEGOPAGE 24
REPORT NO. MP 59-071
MODEL 30
DATE 2 June 1959TABLE 12STANDARD (ROOM) TEMPERATURE PEEL STRENGTHS AFTER
7 DAYS IMMERSION IN SKYDROL 500

Specimen No.	Peel Strength		% Failure		*C.G.L.T. Mils
	Lbs./In.Width	Adhesive	Cohesive		
1E	25	0	100		12
2E	26	0	100		12
3E	25	90	10		12
4E	26	10	90		12
5E	26	0	100		12
6E	26	0	100		12

Avg. 26

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PAGE 15
REPORT NO. MP 59-071
MODEL 30
DATE 2 June 1959

TABLE 13
COMPRESSION STRESS & PEEL STRENGTHS OF ALUMINUM HONEYCOMB SANDWICHES

Spec. #	Calc. Load Lbs.	Failing Load Lbs.	Calc. Core Shear PSI	Failing Core Shear PSI	Req'd. Compress. Stress PSI	Failing Compress. Stress PSI	Peel Strength In.-Lbs. R.T. -65°F	Condition of Test
1	660	735	211	231	50,000	54,894	104	Standard
2	660	760	211	239	50,000	56,761	119	Standard
3			No Flexural Test				55	Standard
4			No Flexural Test				55	Standard
5	660	725	211	228	50,000	54,147	88	After 30 Days 100% Relative Humidity Exposure
6	660	725	211	228	50,000	54,147	106	After 30 Days 100% Relative Humidity Exposure
7	660	750	211	236	50,000	56,014	116	After 7 Days Immersion In JP-4 Fuel
8	660	755	211	237	50,000	56,388	119	After 7 Days Immersion In JP-4 Fuel
9	660	745	211	234	50,000	55,641	116	After 7 Days Immersion In Skydrol 500
10	660	750	211	236	50,000	56,014	116	After 7 Days Immersion In Skydrol 500

Note: All honeycomb specimens were tested using an "A" distance of 4.75 inches and the core ribbon parallel to the 16 inch dimension. Average "h", or centroid distance, was 0.530 inches.